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A RHIZOMORPHIC ROOT-ROT OF FRUIT TREES.

By E. MEAD WILCOX, Ph. D. (Harvard)

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A RHIZOMORPHIC ROOT-ROT OF FRUIT TREES.

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INTRODUCTION.

The early settlers in Oklahoma soon learned that, in many parts of the Territory, fruit culture promised to become a profitable industry. Probably many of these persons brought with them the stones of peaches they had found to be desirable varieties in the northern states, and thus many orchards were planted very shortly after the formal opening of the Territory to settlement. The great importance of apple and peach culture in Oklahoma today renders it imperative that each and all enemies of these trees be given prompt attention.

Fortunately peach curl and peach yellows have not become prevalent and dangerous diseases in Oklahoma while the apple tree is not greatly damaged by the usual parasitic fungi associated with this species in the northern and eastern states. For a few years past the attention of this Station has frequently been called to a root-rot disease of various fruit trees that from all information available seems to be one of great importance. A preliminary examination of the economic pathology of the common cultivated plants of the Territory, made by the author soon after his arrival in the Territory last July, demonstrated the desirability of at once instituting a series of investigations regarding this root-rot. The facts thus far secured are presented in this Bulletin while the results of further experimental work upon the same subject are reserved for some subsequent publication.

By designating the disease under consideration a "rhizomorphic root-rot" I have avoided the confusion arising from applying the term root-rot to rather similar effects produced by various other fungi in a variety of cultivated plants. The internal effects of the rhizomorpha causing this disease are similar to those described by Hartig and others for the rhizomorpha of *Armillaria mellea*; but as will be explained the sporophores arising from this rhizomorpha are entirely different from the typical *Armillaria mellea* and are described in this Bulletin as a new species.

I wish to take this occasion to express my deep sense of gratitude to Mr. O. M. Morris, the Horticulturist of this Station, and to many fruit growers of the Territory for the assistance they have rendered me during the course of the present investigations. The kindness of the Botanists and Horticulturists of the Experiment Stations of other states has enabled me to indicate the present distribution of this disease over the entire United States. To Professor J. C. Whitten of Missouri and Professor A. L. Quaintance of Georgia, among others, I am especially indebted for material furnished. It is a pleasure to acknowledge the constant support and advice I have received from the Director of this Station; without the encouragement he has given, the presentation of my results in this form would have been quite impossible. To Dr. William Trelease and members of his staff, both of the Missouri Botanical Garden and the Shaw School of Botany of Washington University, I am indebted for much assistance, given me during the few weeks I spent in St. Louis in the critical examination of certain literature of this subject there available. My thanks are due Professor C. H. Peck of Albany, N. Y., and Mr. A. P. Morgan of Preston, Ohio for assistance rendered in the identification of the fungus herein described.

HISTORY OF THE STUDY OF PARASITIC HYMENOMYCETES

Parasitic Hymenomycetes as wood destroying fungi do not appear to be very recent products of evolution. For, though the serious study of the fungi themselves and the diseases produced by them was reserved for the last half of the past century, we have records of the occurence of evident wood destroying fungi long previous to that. Hartig 1894 states that he has detected the mycelial strands of *Agaricus melleus* in fossil wood of Cupressinoxylon and Seward 1898, page 111, says "Some good examples of bladder-like swellings, such as occur in the mycelium of *Agaricus melleus* and other recent fungi, have been figured by Conwentz in fossil wood of Tertiary age from Karlsdorf."

The filiform hypogaeous mycelial strands of some of these fungi were known to Linnaeus f. who described them under the name "*Lichen radiciformis.*" Roth subsequently established the genus *Rhizomorpha* to contain such forms and described *Rhizomorpha fragilis.* And though Roth was well acquainted with the anastamosing flattened forms assumed by the subcortical strands of these forms, yet the majority of the writers of his time looked upon the subterreanean and subcortial strands as entirely independent species. The following shows plainly the opinion held by Roth regarding these forms. He says (Catalecta Botanica, page 232) "Sub- arborum cortice

ob pressionem et adaesionem planam figuram adquirit haec Alga magisque anastomat. In fodinis autem metallicis et puteis tectis ubi libere vagare potest sibique plane relicta manet, teres et filiformis est."

Persoon in fact described two species; *Rhizomorpha subterranea* and *Rhizomorpha subcorticalis.* Schmitz 1843 made the first real scientific study of these rhizmorophic forms and showed clearly that the two species described by Persoon were but forms of the *Rhizomorpha fragilis* as had already been suspected by Roth himself.

Schmitz followed the growth of the strands in cultures and noted the strictly apical growth and the phosphorescence of the strands. The following figures were secured by him respecting the rapidity of the apical growth in length of these strands in artificial cultures. The experiment was performed from June 7 to June 12 with a room temperature of about 19 degrees C. A certain apical portion was properly marked off and the figures given represent the length of this portion at the times stated at the heads of the columns.

June 7		June 8		June 9		June 10		June 11	June 12	
7 P.M.	7 A.M.	7 P.M.	7 A.M.	7 P.M.	7 A.M.	7 P.M.	7 A.M.	7 P.M.	7 A.M.	7 P.M.
1.4	2.3	2.6	3.1	3.8	4.1	4.5	5.0	5.6	6.2	6.6

From these figures we see that the average apical growth in length at night was 0.56 lines and during the day 0.48 lines. The experiments performed by Schmitz did not lead him to assign to light any effect upon the growth of the strands.

Attempts to secure and identify the sporophores of these rhizomorphic forms lead to the greatest confusion. Some, with P. de Candolle, placed these forms with the Pyrenomycetes and assigned to them real perithecia. Some of these perithecia were afterwards shown to be the pertithecia of real Pyrenomycetes growing on or near the strands. It is neither proper nor necessary to restate here the various attempts that have been made in the past to assign these rhizomorphic forms to their proper fruiting forms. Suffice it here to state that owing to the researches of Hartig, supplemented by those of Brefeld and others, the connection between the strands under consideration and the proper fruiting forms was established.

Hartig 1873, in a preliminary report upon the parasitism of *Agaricus melleus,* states that "Erdkrebs," a resin-flux disease of Conifers well known to German foresters, is caused by the parasitic ac-

tion of the rhizomorphic strands of the fungus named. Hartig at that time had detected the same disease on the following plants: Pinus sylvestris, Pinus strobus, Pinus pinaster, Abies pectinata, Abies excelsa, Prunus avium, Sorbus aucuparia, Crataegus monogyna, Betula alba and Fagus sylvatica. The careful study of these fungi and the diseases produced by them may be said to date from 1874 when Hartig presented the results of his very extensive researches regarding the parasitism of *Agaricus melleus* and other wood destroying fungi. Hartig 1878 showed for the first time very clearly the internal effect produced by fungi of this character upon the cells of the host.

In America very little attention has so far been given to the study of the parasitic Agaricaceae. Meehan 1891, referring to the studies of Smith on peach yellows, says, page 55, "He will no doubt conclude, as the conductor of this magazine did years ago, that the attack of a mushroom, *Agaricus melleus*, on the peachroots, is responsible for the trouble." And the same author has referred a disease of Rhododendrons to the attacks of the same fungus. See Meehan 1891 A and 1892.

Smith 1894, in his field notes for 1892, mentions under the heading "Root-Rot of Peach" having received specimens of a diseased peach tree from Waco, Texas. He says, page 377, "on examination the entire inner bark was found to have been destroyed by a fungus which produced between wood and bark copious flat, mycelial strands, having a strong smell of mushrooms. Apparently the strands belonged to some hymenomycetous fungus, but there were no organs of fructification by which to identify it. Possibly this decay is the work of *Armillaria mellea*, but no rhizmororphs were found. At any rate it is a disease which has been reported only from the Southwest, no cases ever having been observed by the writer in the peach-growing regions of the northern and eastern United States, where peach yellows is prevalent and where we should expect to find such symptoms frequently if hymenomycetous fungi were the cause of yellows."

Selby 1898 in a Bulletin on peach diseases in Ohio refers to a Root-Rot of peaches that may possibly be referred to the action of some Agaricus. Selby says, l. c., page 235, "In a part of one orchard at Gypsum, Ottawa county, where there is a dense clay subsoil and probably also insufficient drainage, a great many trees have died out. Upon removal, the roots, especially the deeper ones, show extended decay. On these decayed parts there is usually an abundance of the mycelium of some fungus, the whole having at times a characteristic

odor." Selby says in a recent letter to the author under date of 15 December 1900, "I know of this trouble only in clay knolls of Ottawa County."

Further references to the published papers regarding the diseases of fruit trees caused by hymenomycetous fungi may be found in the extended Bibliography at the close of the present paper.

The following list of the host plants of species of the original Genus Agaricus has been compiled to assist in the further study of fungi of this character and of the diseases produced by them. No doubt many of the species named in this list will be found to behave in a strictly parasitic manner towards the host plants under which they are named. In any case many of the species here named are among the facultative parasites and deserve careful attention. Unless otherwise stated the authority for placing the species with the hosts named is Farlow and Seymour 1888-1891. The nomenclature used in the names of hosts is that employed by Sargent in his Sylva.

Abies balsmaea
    mitis Persoon.
Abies picea
    melleus Vahl.—Hartig 1873; von Tubeuf 1893.
Abies sibirica
    melleus Vahl.—Rostrup 1894.
Abies sp. indet.
    austini Peck.
    blakei B. and Cooke.
    purpureofuscus Peck.
Acer barbatum
    saccharinophilus Peck.
    velutipes Curtis.
Acer pseudoplatanus
    melleus Vahl.—Rostrup 1880.
Acer spicatum
    variabilis Peck.
Acer sp. indet.
    albocrenulatus Peck.
    atrocaeruleus Fries.
    bombycinus Schaeffer.
    fulvotomentosus Peck.
    herbarum Peck.
    hirtosquamulosus Peck.
    lignatilis Fries.
    squarrosoides Peck.

Aesculus hippocastanum
comosus albus Peck.
sapidus Kalchb.
Alnus rugosa
aurivellus Batsch.
Alnus sp. indet.
atrocaeruleus Fries.
melleus Vahl.—Rostrup 1880.
Betula alba
melleus Vahl.—Hartig 1873.
Betula papyrifera
ostreatus Jacq.
Betula sp. indet.
alnicola Fries.
luteofolius Peck.
melleus Vahl.—Rostrup 1880.
sapidus Kalchb.
semicaptus B. and Cooke.
Carpinus sp. indet.
melleus Vahl.—Rostrup 1880.
Castanea dentata
americanus Peck.
sublateritius Schaeffer.
Castanea sp. indet.
corticolous Schum.
melleus Vahl.—Mathey 1898; Planchon 1878.
Crataegus monogyna
melleus Vahl.—Hartig 1873.
Diospyros sp. indet.
meliigena B. and Cooke.
Eucalyptus sp. indet.
sacchariferus B. and Cooke.
Fagus americana
appendiculatus Bull.
atrocaeruleus Fries.
heteroclitus Fries.
leaianus B.
lignatilis Fries.
limonellus Peck.
mucidus Schrad.
niger S.
sapidus Kalchb.

subcoerulea Peck.
tintinnabulum Fries.
Fagus sylvatica
melleus Vahl.—Hartig 1873.
Fagus sp. indet.
melleus Vahl.—Jubainville 1879; Rostrup 1894.
mucidus Schrad.—Massee 1899.
Fraxinus ornus
melleus Vahl.—Fekete 1879.
Fraxinus sp. indet.
haerens Peck.
melleus Vahl.—Cieslar 1899.
Hicoria ovata
chryophlebius B. and Rav.
niger S.
Hicoria sp. indet.
atrocaeruleus Fries.
Juglans sp. indet.
melleus Vahl.—Kirchner 1890.
Larix americana
strobilinus Peck.
Larix larix
melleus Vahl.—Hartig 1873.
Larix sp. indet.
cerrusatus Fries.
melleus Vahl.—Hartig 1873.
serotinus Schrad.
Liquidambar styraciflua
niger S.
Liriodendron tulipifera
glandulosus Bull.
ulmarius Bull.
Magnolia sp. indet.
conigenoides Ell.
Melia azedarach
corticola L.
meliigena B. and Cooke.
Morus alba
adiposus Fries.
Morus sp. indet.
melleus Vahl.—Berlese 1885; Gibelli 1879.
velutipes Curtis.

Olea sativa
    melleus Vahl.—Carnoso 1885; von Thuemen 1885.
Picea mariana
    hiemalis Osbeck.
Picea sitchensis
    melleus Vahl.—Rostrup 1894.
Pinus laricio
    melleus Vahl.—Hartig 1873.
Pinus pinaster
    melleus Vahl.—Hartig, 1873.
Pinus strobus
    melleus Vahl.—Dudley 1888; Fischbach 1885; Rostrup 1894; Wachtl 1886.
Pinus sylvestris
    melleus Vahl.—Hartig 1873; Rostrup 1894.
Pinus sp. indet.
    campanella Batsch.
    chrysophyllus Fries.
    conigenoides Ell.
    conigeus Presoon.
    flavescens Peck.
    intertextus B. and Cooke.
    nidulans Peck.
    niphetus Ell.
    porrigens Peck.
    rubescentifolius Peck.
    sapineus Fries.
    scalpturatus Fries.
    stipitarius Fries.
    striatulus Persoon.
    sulfureoides Peck.
Populus deltoidea
    melleus Vahl.—Jubainville 1879; Rostrup 1894.
Populus nigra
    ostreatus Jacq.
Populus sp. indet.
    atrocaeruleus Fries.
    fibula conicus Peck.
    fulvotomentosus Peck.
    haustellaris Fries.
    melleus Vahl.—Cieslar 1899; Rostrup 1880.
    salignus Schrad.

Prunus avium
    melleus Vahl.—Hartig 1873.
Prunus cerasus (Cherry)
    melleus Vahl.—Kirchner 1890.
    parasitica sp. n.
Prunus domestica
    melleus Vahl.—Hartig 1894.
Prunus persica (Peach)
    melleus Vahl.—Kirhner 1890; Meehan 1891; Smith 1894.
    parasitica sp. n.
Prunus spp. (Plum)
    melleus Vahl—Kirchner 1890.
Pseudotsuga mucronata
    melleus Vahl.—Rostrup 1894.
Pyrus malus
    adiposusu Fries.
    corticola Peck.
    melleus Vahl.—Kirchner 1890.
    parasitica sp. n.
    pulvinatus Peck.
Quercus macrocarpa
    parasitica sp. n.
Quercus minor
    parasitica sp. n.
Quercus nigra
    parasitica sp. n.
Quercus prinoides
    parasitica sp. n.
Quercus sp. indet.
    applicatus Batsch.
    bombycinus Schaeffer.
    californiensis B. and Cooke.
    erinaceus Fries.
    gracillimus Weinm.
    melleus Vahl.—Cieslar 1899; Hartig 1895, 1896; Jubainville 1879; Rostrup 1880.
    sapidus Kalchb.
    squarrosus Mull.
    nidulans Peck.
    petaloides Bull.
    strobilinus Peck.
    spectabilis Fries.

sublateritius Schaeffer.
tessulatus Bull.
Rhododenron maximum
rhododendri Peck.
Rhododendron sp. indet.
melleus Vahl.—Meehan 1891 A, 1892.
Robinia pseudacacia
melleus Vahl.—Gillot 1884.
spectabilis Fries.
Salix alba
melleus Vahl.—Rostrup 1880.
Salix capraea
melleus Vahl.—Rostrup 1880.
Salix sp. indet.
disseminatus Peck.
melleus Vahl.—Cieslar 1899.
salignus Schrad.
velutipes Curtis.
Sorbus aucuparia
melleus Vahl.—Hartig 1873; Rostrup 1880.
Taxus brevifolia
leaianus B.
terraeolus Peck.
Thuja occidentalis
melleus Vahl.—Treichel 1877.
Tilia americana
aurivellus Batsch.
coloreus Peck.
tiliophillus Peck.
Tilia sp. indet.
eximius Peck.
Tsuga canadensis
bellulus Peck.
campanella Batsch.
epiterygius Scop.
melleus Vahl.—Dudley 1888.
porrigens Peck.
rugosodiscus Peck.
striatulus Peck.
succosus Peck.
Ulmus sp. indet.
corticola Schum.

enosmus B.
mastrucatus Fries.
melleus Vahl.—Cieslar 1899.
sapidus Kalchb.
subareolatus Peck.
ulmarius Bull.

Vitis sp. indet.
applicatus sarmenticius Sacc.
melleus Vahl.—Belluci 1892; Berlese 1897; Dufour 1888, 1894; Jablonowski 1899; Kirchner 1890; Linhart and Mezcy 1899; McCarthy 1893; Millardet 1880, 1884, 1885, 1885A; Pierce 1892; Prillieux et Delacroix 1896; Schnetzler 1879, 1886; Scribner 1890; Viala 1894, 1894A.

DISTRIBUTION OF THE DISEASE IN OKLAHOMA AND THE UNITED STATES.

I have represented graphically on Plate 11 the distribution of this rhizomorphic root-rot disease in Oklahoma and throughout the United States so far as the information at hand would allow me. California and Oregon should have been marked as states from which the same disease is reported. According to the data available the disease is therefore confined largely to the Southwest as stated by Smith 1894. The author is however of the opinion that further studies of the matter will show that the same disease is prevalent throughout the United States where orchards have been planted out on recently cleared timber lands.

So far as I am aware the true *Armillaria mellea* does not occur in Oklahoma but the disease under consideration caused by *Clitocybe parasitica* sp. n. is very common in the counties marked in fig. 24. The same disease has been reported to me from some other counties by fruit growers but I have not been able to establish the fact by personal examination of diseased roots. Within the counties noted the local distribution of the disease accords with the location of the local timber belts. For further notes regarding this matter of local distribution see the chapter on Remedial and Preventive Measures.

Further facts regarding the distribution of the disease under consideration and of *Armillaria mellea*, *Armillaria mellea crannulata* and *Clitocybe parasitica* are very much desired by the author. Notes regarding the parasitic character of any of these fungi should be accompanied by specimens and spore prints if possible.

SYMPTOMOLOGY.

The symptoms of this disease are so characteristic that no one should experience any great difficulty in correctly diagnosing any suspected cases. Perhaps the most characteristic effect of the attacks of this fungus is the great exudation of gum about and from the crown of the diseased trees. This flow of gum occurs in apple, peach and cherry trees according to my own observations and is reported for the apricot tree by Woodworth 1896. It frequently happens that the amount of this gum to exude is so great that it unites with the soil about the base of the tree to such an extent as to form a mass of cemented soil about the tree. In many cases this mass of gum-cemented soil will become hardened to form a sort of cast about the crown and larger roots of the trees.

The yellow coloration of the leaves is usually one of the prominent symptoms of the disease. In many cases however the leaves wilt rapidly during the growing season instead of becoming yellow. This rapid wilting of leaves is the first external evidence afforded that the root system of the tree and consequently its absorptive ability have been greatly reduced.

In every case the examination of trees affected with this disease will reveal the presence of the typical subcortical strands and perhaps also the very characteristic subterranean rhizomorphic form adhering to the roots. In some cases the subcortical strands of mycelium impart to the root a peculiar mushroom flavor which cannot be mistaken; Smith 1894 and Selby 1898 in their diagnoses of similar diseases have made mention of this same peculiarity.

The groups of sporophores found about the base of the trees will afford the most positive evidence of the presence of this disease. But unfortunately this evidence comes too late for the application of any remedial agent; for the sporophores seldom appear about the crown of the tree until the disease has so far progressed that no preventive nor remedial measures can be applied.

A careful histological examination of the diseased parts will show the characteristic swollen hyphae of fungi of this character. But this matter can better be discussed in the following chapter.

CHANGES IN THE WOOD CAUSED BY THE FUNGUS.

The classical researches of Hartig have paved the way for the study of the pathological modifications of cells and cell contents by the wood-destroying fungi. So far as the literature at hand is concerned I am unable to find any accurate description of the internal

effects of fungi of this character upon any of the fruit trees herein named. Several matters concerning this subject are now under investigation and will be presented in some future publication.

Careful examination of the diseased roots of any of the fruit trees named will reveal in many cases some of the typical black rhizomorphic strands, previously described, adhering closely to the cortex. A little care in following these along the root will enable one to establish the connection of some of them to the subcortical strands. The author has detected some cases in which these black rhizomorphic strands had entered directly through the cortex of perfectly healthy trees. The subcortical strands are as already indicated flattened bands of hyphae. These are mostly located directly between the cortex and the cambium. These subcortical strands do not possess the same histological structure as do the subterranean strands. They consist simply of masses of hyphae which are not arranged to form a definite external cortical portion of more compact fibers such are seen in the typical subterranean strands.

From these subcortical strands branches are given off that enter the wood usually through the medullary rays. Plate 7, fig. 11 shows clearly the great masses of hyphae that are often to be seen forming radial plates running from cortex to the duramen, or even to the pith of the stem. This great growth of hyphae parallel with the medullary rays soon leads to the formation of radial cracks in the wood. (Compare Plate 7, fig. 10.)

The rapid vertical movement of the hyphae is made in the vessels and tracheids of the xylem. From the hyphae moving in the xylem frequent branches are given off that enter the cells of the medullary rays and cause there a complete destruction of the cell contents. (Compare Plate 10.) In all the cases examined these hyphae find their way into the cells only through the pits. It is not at all infrequent to find these hyphal branches within the cell forming loops about the nucleus and thus finally causing its complete disintegration. The other cell contents soon become massed about the mucleus and the whole cell becomes filled with a gum or gum-resin. The later escapes and fills the vessels and tracheids causing the characteristic gum-exudation of the disease and interfering also with the ascent of sap through the wood.

The structural changes in the wood cells induced by the mycelium of this fungus are very slight indeed. The cortex is rapidly disintegrated however and in advanced stages of decay is seen in the form of shreds and strips adhering to each other in many cases simply by means of the mycelium connecting them.

Some technical points regarding the chemical changes induced in the wood by this fungus and other structural changes induced are reserved for another publication.

SPREAD OF THE FUNGUS.

A fungus of this type is well provided with means to insure its rapid distribution throughout large orchards. The spores, that are produced in such large numbers, are easily scattered about and each one may, under proper conditions, give rise to a mycelium and the typical sporophores. Perhaps the beetles that are often seen eating the old pilei are of some value in distributing the spores, but this point needs some further investigation.

The most fertile source of infection is certainly found in the several sorts of mycelial strands produced by this fungus. The subcortical mycelium in an old stump or even a diseased tree may give rise to the purplsh-black rhizomorphic strands and these will grow out in the soil to a considerable distance. In one case the author was able to trace these subterranean strands for a distance of about ten feet from a partially decayed oak stump. One of these same strands was followed, at an average depth under the surface of the soil of ten inches, for about eight feet where it was found entering the cortex of a living "Ben Davis" apple tree. None of the other roots of this tree were diseased and it was plain that the first entrance of the mycelium had been made at this point, out on one of the smaller roots at least six feet from the trunk of the tree.

Though the first entrance to the tree is generally made by the mycelium through the cortex of a small root, yet cases were found in which the mycelium had evidently entered the crown of the tree first and then spread out through the smaller roots and up into the trunk. As a rule the mycelium does not grow up in the trunk above about three feet from the crown. In fact in many cases no trace of the mycelium can be detected in the trunk more than five or six inches above the crown.

SPOROPHORES OF THE FUNGUS.

I was naturally led at the beginning of these investigations to suspect that the sporophore of the fungus whose mycelium we have described would prove to be the common *Armillaria mellea* of Europe, whose parasitic character has been so well shown by Hartig and others. Smith 1894 and more recently Von Schrenk 1901 have both suspected that the fungus causing this root-rot disease was *Armillaria mellea*. Von Schrenk 1901, page 52, says "I suspect that pos-

sibly this fungus when determined will prove to be the same as a fungus very common in both Europe and America, the *Agaricus melleus* or honey mushroom."

The author was so fortunate last fall as to secure a large number of the sporohores of this fungus in all its stages. It was noted at once that it could not be placed in the Genus *Armillaria* owing to the absence of the annulus from all the stages. Peck 1896 however has described a form without the annulus under the name *Armillaria mellea exannulata.* He says, l. c. page 167, "Variety *exannulata* has the cap smooth and even on the margin, and the stem tapering at the base. The annulus is very slight and evanescent or wholly wanting. The cap is usually about an inch broad, or a little more, and the plants grow in clusters, which sometimes contain forty or fifty individuals. It is more common farther south than it is in our State, and is reported to be the most common form in Maryland." McIlvaine 1900 refers to the same variety and fig. 2 of his Plate 16 is a colored figure of this form.

Our form differs from the above variety in several important respects. The pileus is not smooth in ours and the plants are very much larger in our species. Besides it seems that in the typical *Armillaria mellea exannulata* there is present a veil in the younger stages while there is none at any stage in our species. Professor Peck in a letter under date of 28 December 1900 says "In this (*Clitocybe monodelpha Morgan*) the lamellae are more strongly decurrent and there is no evidence of a veil even in the young stages. In the other (the variety *exannulata*) there is."

The original description of the *Clitocybe monadelpha* was given by Morgan 1893. I reproduce here in full his original description of this form since the original description may not be easily accessible to all interested. Morgan says, page 69, "39, *A. monadelphus*, n. sp.—Densely caespitose. Pileus fleshy, convex, then depressed, at first glabrous, then scaly, honey color, varying to pallid-brownish or reddish. Stipe elongated, solid, crooked, twisted, fibrous, tapering at the base, pallid-brownish or flesh-color. Lamellae short, decurrent, not crowded, pallid flesh-color. Spores white, a little irregular .0076x.0055 mm. (See Plate IV,)" Morgan's original figure of this form is reproduced in our Plate 6. As to its habit Morgan says on same page "On the ground in wet woods from spring to late autumn." The figures of this species given on Plate 51 by Peck 1898 have not been accessible to the author during these studies but the description given by Peck in the report noted agrees entirely with that of Morgan.

Regarding the habit of the species Morgan says in a recent letter under date of 2 January 1901, "It (*A. monadelphus*) is never a parasite, however. It grows about old stumps or about trees with dead roots, starting out of the wood by a single point and developing into a multitude of stipes and pilei."

The fungus causing the disease we have described differs from *Armillaria melleaexannulata* in the particulars mentioned above and from the *Clitocybe monadelpha* in the following particulars:

(a) The pileus is rough from the first with small scales and small warts.

(b) the stipe is never twisted.

(c) pileus is regular and the lamellae are evenly decurrent and therefore our species cannot be placed in the same section of *Clitocybe* with *C. monadelpha.*

(d) our species is always parastic in habit.

It seems best therefore to describe our species as a new species with *Clitocybe monadelpha* as its nearest relative in the Genus. Our species belongs in the Section Disciformes which is thus charactarised by Winter 1884;—Pileus somewhat equally fleshy, at first convex, then plane or depressed, margin obtuse, regular. Lamellae adnate or evenly decurrent.

Clitocybe parasitica sp. n.

Pileus fleshy, at first strongly convex, changing to umbonate and finally becoming plane or depressed; from the first the pileus is covered, in the center especially, with small scales and warts of the same color as the remainder of the pileus. Margin at first strongly involute but gradually becoming horizontal or slightly elevated; frequently splitting radially at maturity. Pileus honey color changing with age to pale yellowish or reddish brown. Mature specimens generally measure 7 to 8 cm in width.

Stipe is solid, sinuous, but never twisted, generally tapering some towards the base and never swollen at the base; glabrous but frequently becoming distinctly scaly by the transverse breaking of the outer fibres (See plate 5); in mature specimens the stipe is often as much as 12 to 15 cm in length and 0.5 to 1 cm in diameter.

Lamellae equally decurrent about the stipe, distant, averaging 80 to 125 in number, rosey white changing with age to yellowish brown in spots or to uniform dark flesh color.

Spores white, elliptical to subspherical. 5.6—6.0=6.4—7.4 mu.

The species grows in dense clusters from the crowns of living trees and the stumps of dead trees but is strictly a parasitic form in

both cases. The sphorophores are formed from September to October. The great crowding in the clusters often leads to considerable malformations of both pilei and stipes. It has been found by the author on living trees of peach, apple, cherry and four species of oak in Oklahoma.

The species produces a subterranean rhizomophic form similar to those associated with *Armillaria mellea* and so well described by Hartig, DeBary, Schmitz and others. Its color is black in the mature specimens but the young growing tip is rosy white changing gradually with age to purplish and then to black. The phenomenon of phosphorescence has been detected by the author in these rhizomorphic strands.

REMEDIAL AND PREVENTIVE MEASURES.

The greater part of our knowledge concerning the proper remedial measures to be applied against this and other wood destroying fungi is derived from the wide experience of the foresters of Europe. Among the strictly remedial measures none are of greater importance that the isolation of diseased trees by ditching. If a single tree in the midst of the orchard is found to be diseased, a ditch should at once be dug around it to prevent if possible the further spread of the disease by the subterranean mycelial strands. This ditch should be dug at a distance of about ten feet from the tree, i. e., with a diameter of about twenty feet. The ditch should be about one foot wide and about two feet deep with vertical walls. The same measures are to be adopted to protect a group of diseased trees that are found in the orchard. In this case the ditch may be dug so as to include all the trees in the group. It is possible that the burning of brush in this ditch will kill the rhizomorphic strands and prevent further spreading. So far as the author is aware this method has never been practiced to any great extent in America though in Europe it seems to have proven effective in combating this and similar diseases.

It cannot too strongly be insisted upon that all fruit trees that are found to be diseased should at once be removed from the orchard. Care must also be taken in such cases to remove and burn not only the trunk but all the larger roots and especially all those diseased. Perhaps a tree will bear salable fruit after the mycelium of this fungus has entered its root system but it is a near sighted system and poor business judgment to allow such a tree to stand, when it is remembered that thereby all the other trees in the orchard are being endangered.

Too great care cannot be taken to avoid cutting or otherwise injuring the roots of the trees by ploughing or other cultivation. Though the mycelium of this fungus is able to enter the cortex of perfectly healthy roots, yet its progress, as well as entrance, is greatly facilitated by wounds of any character. In one of the orchards visited by me last fall it was apparent that in some cases the mycelium of this fungus had first entered the healthy roots through wounds made by the plough in cultivating between the rows.

The same statements apply to the matter of ridding all trees promptly of borers. For it is a fact that this and many other fungi find ready entrance to trees through the holes made by borers and other insects. The relationship existing between insects of this type and the wood destroying fungi has not been determined in many cases. Lindeman 1883 and Wachtl 1886 have established the fact that *Tomicus typographus*, a common wood-boring beetle of Europe, provides ready entrance for the attacks of *Armillaria mellea* on pine roots. The author has seen several cases in which an entrance into apple trees has been made by the mycelium of *Clitocybe parasitica* through the holes made by the flat headed apple borer, *Chrysobothris femorata*. Evidently therefore careful atention must be given to insects of this character in combating this root-rot fungus.

My attention has frequently been called to a practice among some fruit growers of placing in the bottom of the hole, in which they are about to set a tree, a quantity of chips from their wood pile. In many of these chips there is sure to be found some of the mycelium of this fungus and the introduction of the disease into the orchard is the result of this practice in many cases. For it is a well known fact that each small piece of mycelium of these fungi is capable of remaining dormant for long periods and of again producing, when placed under proper conditions, the mycelium and even the normal sporophores of the species.

It was early found in these investigations that the disease was largely or entirely confined to those orchards that were planted on recently cleared timber land. This matter has been referred to in the discussion of the local distribution of the fungus. In fact the disease has never been reported in this Territory from orchards planted out on real prairie soil. Subsequent investigations have afforded abundant proof that the fungus described in this Bulletin is common as a parasite and also as a saprophyte on various species of oak in this Territory. For a complete list of the host plants

of this fungus reference should be made to the host index as given in the chapter entitled, History of the Study of Parasitic Hymenomycetes. Consequently old oak stumps or even dead oak roots remaining in the soil are apt to become fertile sources of the infection of the healthy trees planted in that same soil. From the above it follows that it is the part of wisdom to remove all old oak stumps from the orchard and to dig up all roots of such trees remaining in the soil. These should be carefully burned and in no case allowed to remain on the surface of the soil.

From the nature of the disease the application of any fungicide as a remedial agent cannot be recommended at all. And there is much doubt if their application to the soil will effectually prevent the spread of the mycelium through the soil from diseased trees or stumps. This is made probable from the fact that these fungicides are apt to lose their effectiveness in the soil through chemical combinations with other things present in the soil. Woodworth 1896 says, page 235, "We have recommended the removal of a large amount of earth, the lining of the hole with iron or copper sulphate, and then filling it with new earth, and planting; apparently good results were obtained." So far as I know this method has not been tested by persons in Oklahoma who desired to replant spaces left on removing dead trees.

It is very doubtful if any great good will result from the "liming" of the soil or from mixing large amount of wood ashes with the soil. Neither of these methods would be of the slightest value as remedial methods and further tests must be made before any value is ascribed to them as preventives of the further spreading of the mycelium.

And though thorough cultivation of the soil in orchards is always to be recommended for other reasons yet this does not tend to greatly reduce the spread of this disease. The thorough cultivation of cleared timber land in other crops before planting an orchard is of course to be recommended. Perhaps in this fashion the fungus may simply be cultivated out of existence.

In view of all that has been said it is plain that it is not advisable to replant trees in holes from which diseased ones have just been removed unless perfect precautionary measures have been taken to rid the soil of all traces of the mycelium. And it is even doubtful if new trees should ever be planted out between the rows of diseased ones.

And finally all sporophores that are found should be burned. The fungus under consideration was found to be edible and perhaps

a thorough mycophagist would enjoy reducing the chance of infection by collecting the sporophores from all trees in the orchard and woods and eating them.

The search for disease resisting varieties will probably prove a failure and is a method that has in similar cases not yet proven itself entirely practical. The fact that this fungus and other similar ones are found as parasites on such widely different species as noted above would of itself discourage the attempt to secure a disease resisting variety.

SUMMARY.

(1) The root-rot disease herein described is found in many of the orchards of the Southwest and is very common throughout many parts of Oklahoma.

(2) The fungus causing this disease is here described as a new species, *Clitocybe parasitica.* This species is related to *Clitocybe monadelpha Morgan* and has the typical subterranean rhizomorphic strands described for *Armillara mellea Vahl.*

(3) The disease has been found in peach, apple and cherry trees here in Oklahoma. The same fungus is a common parasitic and saprophytic form on four species of oak in Oklahoma.

(4) The damage done by this disease cannot accurately be estimated from the data at hand but in many cases whole peach and apple orchards have been destroyed by it in two years.

(5) No practical remedial measures can be suggested for individual trees but isolation of diseased trees by ditches is recommended to prevent the spreading of the fungus through the orchard. Orchards should never be planted out on soil known to contain old oak stumps or roots or any of the mycelium of the fungus described.

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EXPLANATION OF THE PLATES.

PLATE 1.

View showing a common location of orchards in close proximity to oak clearings or woods. About fifty per cent of the peach trees and about fifteen per cent of the apple trees in this orchard were found to be diseased, while on the trunks of many of the trees were found groups of the sporophores of *Clitocybe parasitica, sp. n.* The photograph from which this plate was made was taken near Perkins, Oklahoma, in October, 1900.

PLATE 2.

Photograph showing a living apple tree, in the above orchard, that was bearing a fair crop of apples in spite of the fact that its

root system was found to be badly injured by this disease. About the base of the tree may be seen a group of the sporophors of *Clitocybe parasitica, sp. n.*

PLATE 3.

Shows a group of the sporophores of *Clitocoybe parasitica* taken from the base of an apple tree. (The tree was about 6 inches in diameter.)

PLATE 4.

Fig. 4 represents *Armillaria mellea exannulata* Peck. This plate was made by permission of the publishers from a photographic reproduction of the figure in Plate 16 of McIlvaine 1900.

Fig. 5 shows the typical *Armillaria mellea.* It is a reduced copy of Plate 2 given by Taylor 1892. Used by permission of the Division of Publications, U. S. Dept. of Agr.

PLATE 5.

Upper right hand figure is from a photograph of a young sporophore of *Clitocybe parasitica* found growing on an apple tree. X 1.

Upper left hand is from a photograph of the under side of the same sporophore. X 1 1-3.

Lower figure is from a photograph of a group of the young sporophores taken from a peach tree in October. X 1.

PLATE 6.

Shows the original figure given by Morgan 1893 for Agaricus (Clitocybe) monodelphus. The plate was made from Plate 4 in Morgan 1893, by permission of the author.

PLATE 7.

Fig. 10 shows a cross section of an apple tree trunk, about six years old, in which the mycelial strands of the fungus are so numerous that the radial cracking of the trunk has resulted. The light colored triangular portion of the wood is the only part remaining alive.

Fig. 11 shows the longitudinal radial section of the same trunk. Great white sheets of the mycelium are seen near the center of the figure.

PLATE 8.

Shows a typical subterranean rhizomorphic strand of *Clitocybe parasitica sp. n* found adhering to and entering at one point the root of a cherry tree. The scale is a centimeter measure.

PLATE 9.

Fig. 13 shows a longitudinal section of a mature sporophore of *Clitocybe parastica sp. n.* Figure 14, 15 and 16 represent longitudinal sections of younger sporophores of the same species. Fig. 17 shows the typical twisting of the stipe of *Clitocybe monadelpha* Morgan. Figure 18 shows a common shape of the basal region of the stipe of *Armillaria mellea* Vahl. Fig. 19 is a longitudinal view of the pileus of our species taken to one side of the stipe.

PLATE 10.

Fig. 20 represents the hyphae of this fungus entering the cells of the medullary ray, as seen in a radial-longitudinal section, of the apple tree stem. At *b* is the large hypha whose branches have entered the cells and are seen passing from cell to cell through the pits. *a* shows the end of one of the branches that has just passed through a pit in the cell wall. On the opposite side of the wall is one branch in close contact with the partly disintegrated nucleus of the cell. At *c* is shown one of the swollen hyphae, also in close contact with a nucleus which it has destroyed.

Figure 21 shows the branches of a hypha, found in one of the pitted tracheids of the apple stem, passing from one cell to another through the pits at *a* and *b*. Fig. 22 is a diagrammatic representation of the stoppage of the tracheids by the gum exudation shown at *a*. Medullary rays are shown at *b*.

PLATE 11.

Fig. 23 shows graphically the distribution of the disease herein described over the United States. The States from which it is reported are marked with the cross lines. The plate for this figure was prepared from a photographic reproduction of the map found on the outside cover of the Experiment Station Record. California and Oregon should have been noted among the States in which the disease is reported.

Fig. 24 shows in the same manner the known distribution of the disease throughout Oklahoma.

PLATE I.

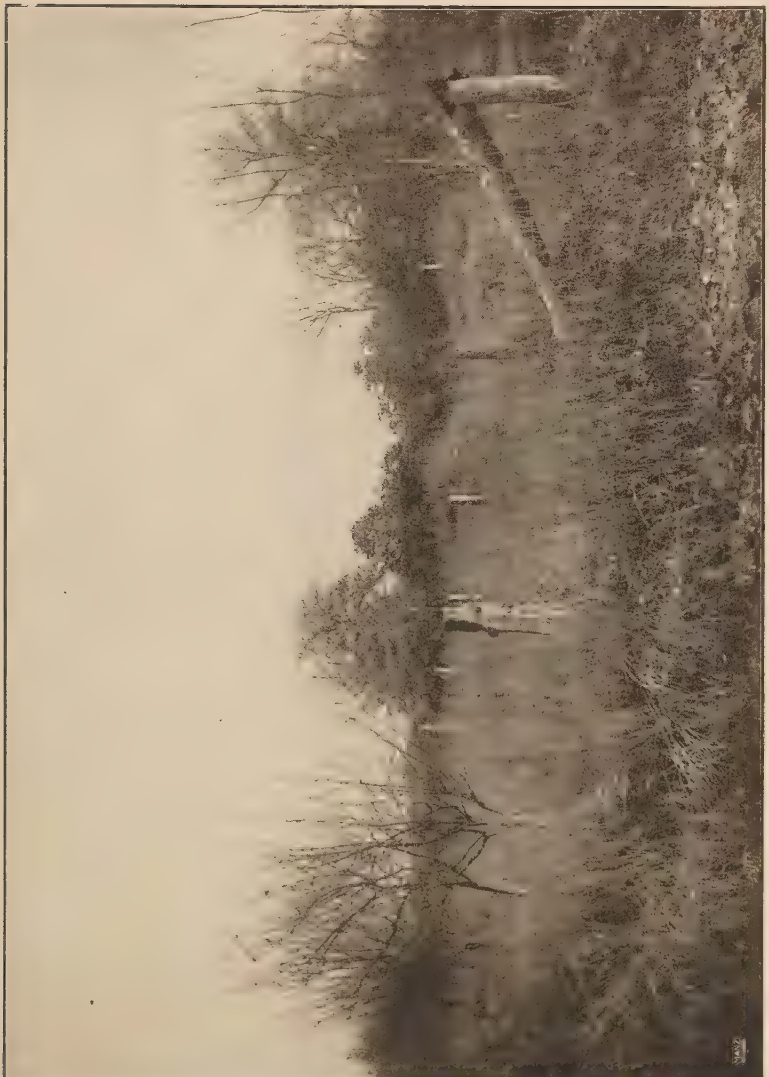


PLATE II.

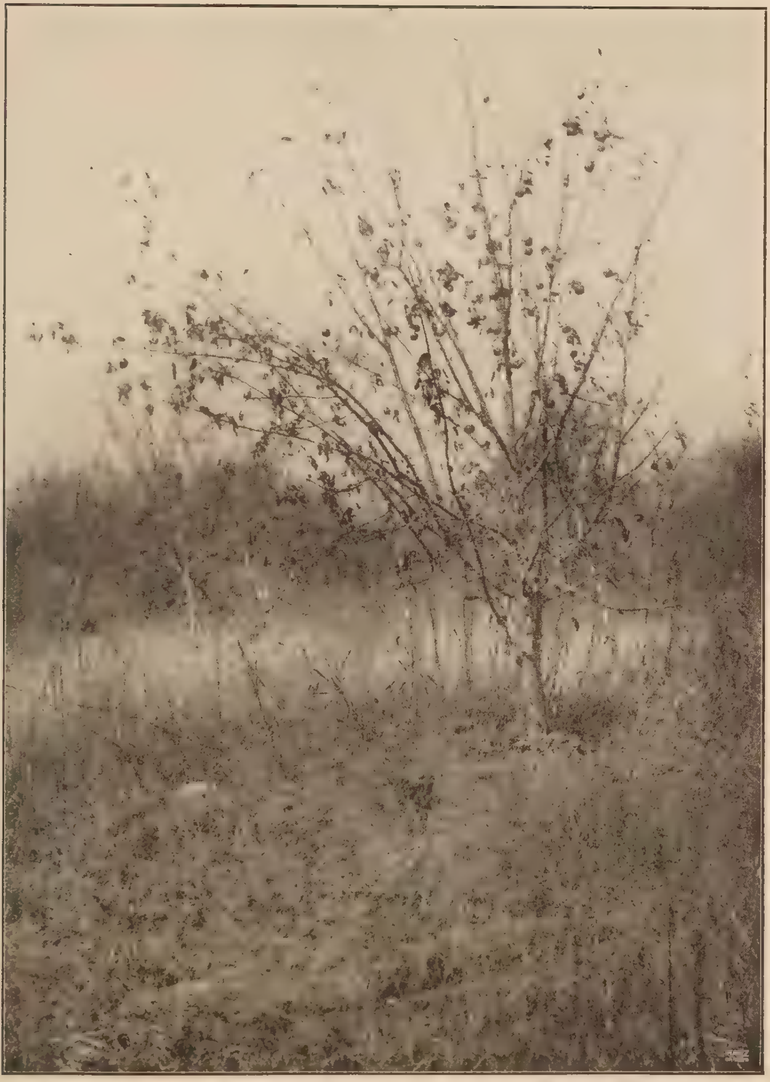


PLATE III

PLATE IV.

Fig. 5.

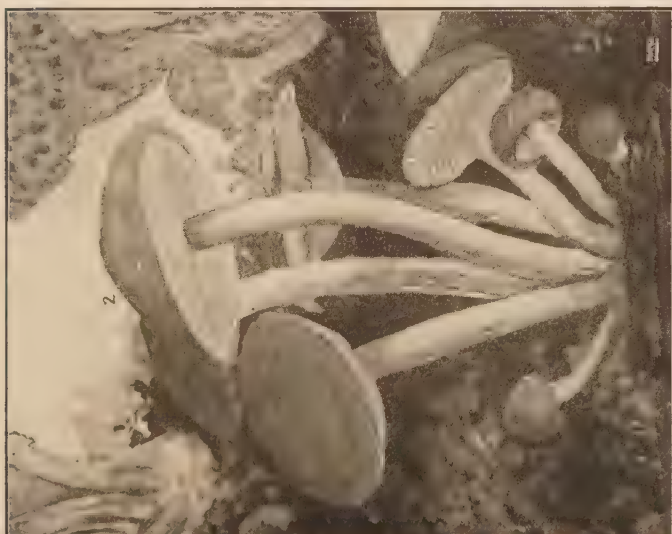


Fig. 4

PLATE V.

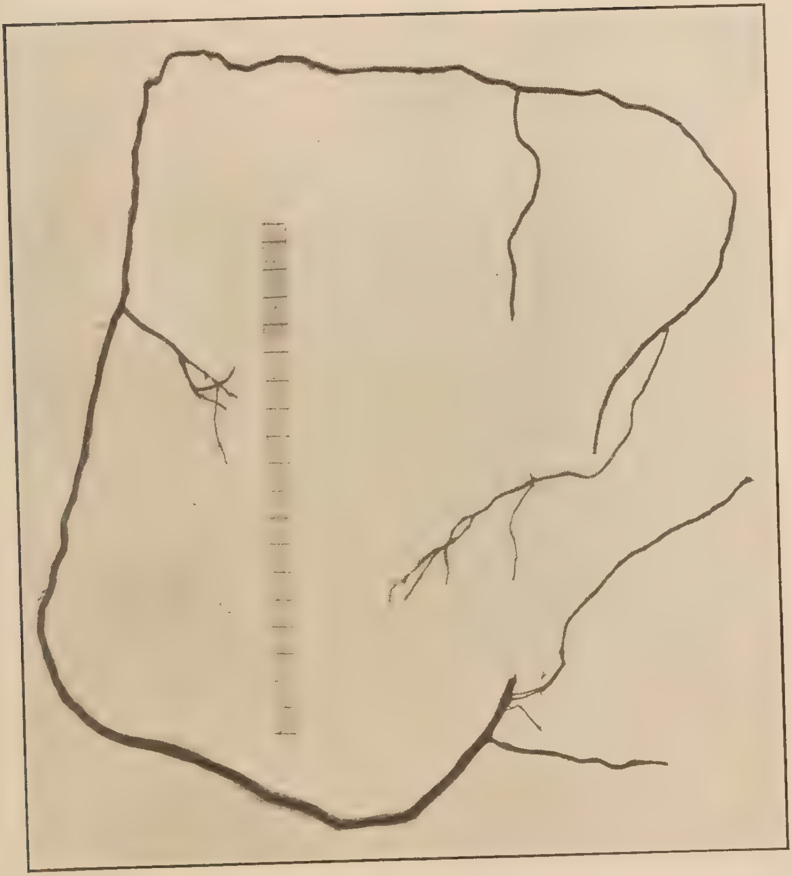
PLATE VI.

PLATE VII.

Fig. 11.

Fig. 10.

PLATE VIII.



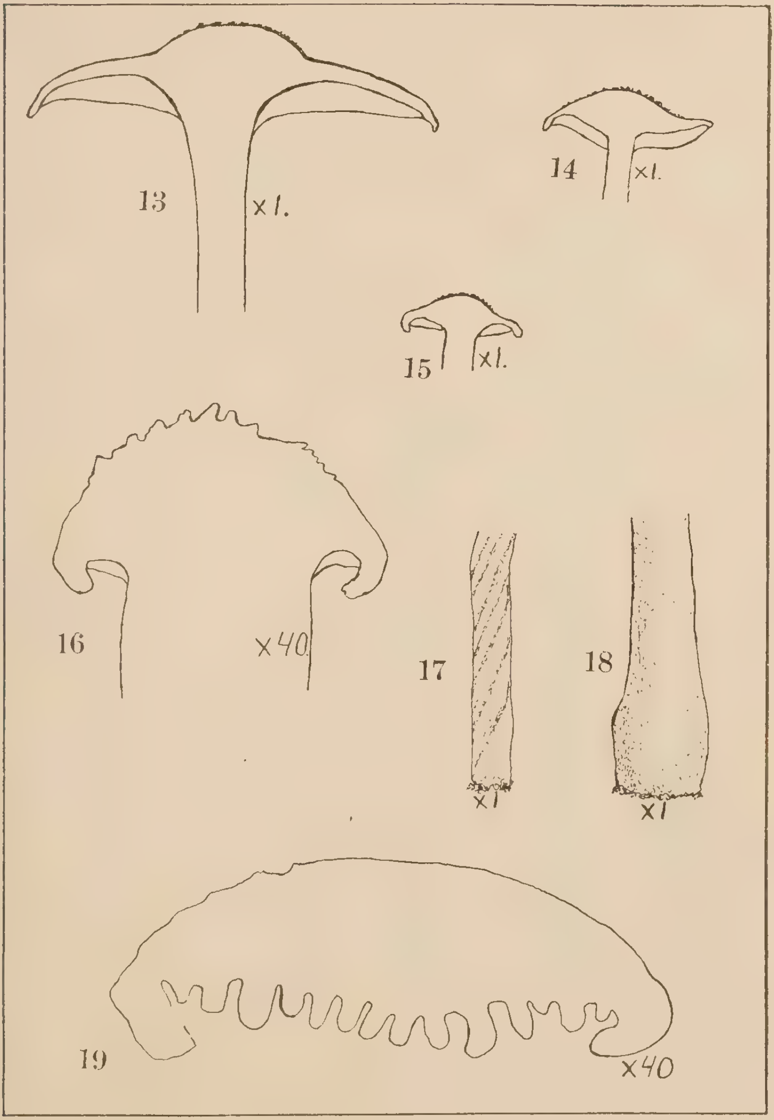

13
x1.
14
x1.
15
x1.
16
x40
17
x1
18
x1
19
x40

PLATE X.

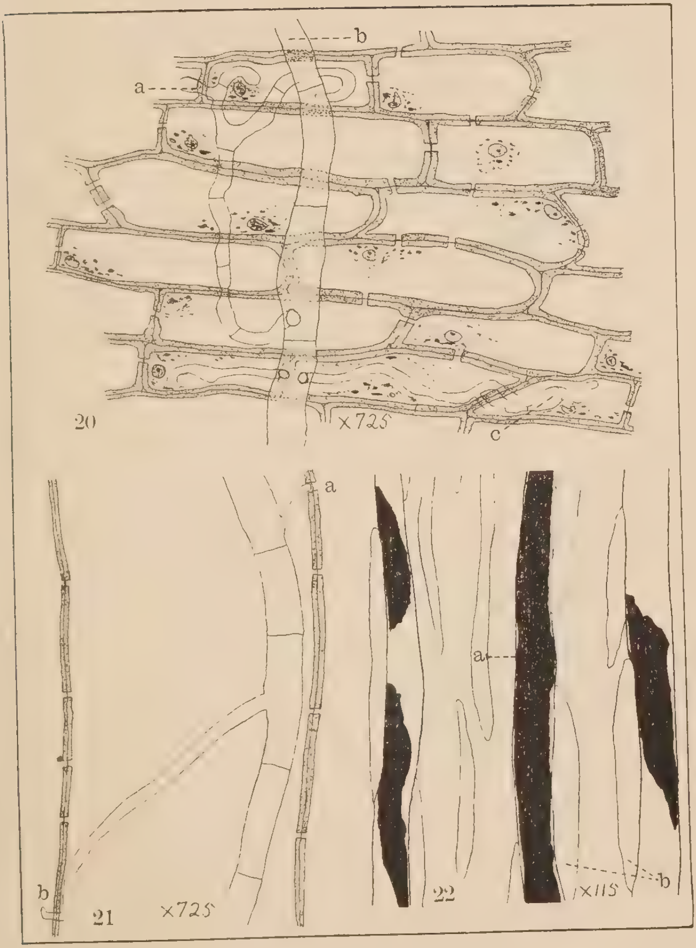


PLATE XI.

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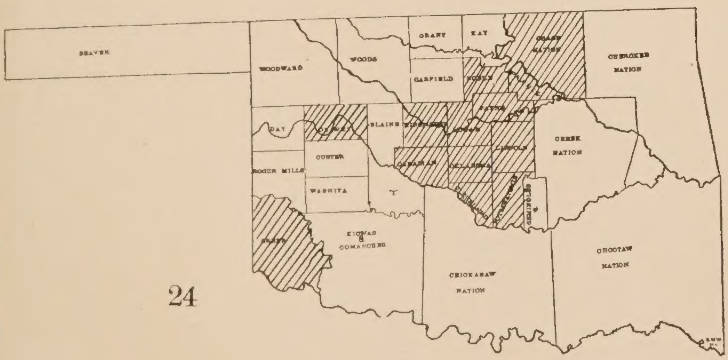

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